Basking shark (*Cetorhinus maximus*) occurrence in relation to zooplankton abundance in the eastern Adriatic Sea

by

Alen SOLDO (1), Davor LUČIĆ (2) & Ivan JARDAS (1)

ABSTRACT. - Basking shark is a rather rare but constantly present species in the eastern Adriatic Sea. However, over the period 2000-2002 their occurrence in that area highly increased. Based on previous presumption, this paper investigates relations between zooplankton abundance and basking shark occurrence. It appears that increased shark occurrence is not directly influenced by changes in temperature and salinity. However, obtained data suggest relative importance of copepods, especially of *Calanus helgolandicus*, in relation to the occurrence of basking sharks.

RÉSUMÉ. - Présence du requin pèlerin (*Cetorhinus maximus*) en rapport avec l'abondance de zooplancton en mer adriatique orientale.

Le requin pèlerin est une espèce plutôt rare, mais constamment présente en mer Adriatique orientale. Au cours de la période 2000-2002 son occurrence dans ce secteur a fortement augmenté. Sur la base de cette présomption, cet article étudie les relations entre l'abondance de zooplancton et les occurrences du requin pèlerin. Il s'avère que la présence accrue de ce requin n'est pas directement influencée par des changements de la température et de la salinité. Cependant, les données obtenues suggèrent un lien entre la densité des copépodes, particulièrement de *Calanus helgolandicus*, et les occurrences de requins pèlerins.

Key words. - Cetorhinidae - *Cetorhinus maximus* - Basking shark - Copepods - *Calanus helgolandicus* - Adriatic Sea.

Basking shark, *Cetorhinus maximus* (Gunnerus, 1765), is a coastal/pelagic shark found in boreal to warm temperate waters of the all seas. It is a highly seasonal species, noteworthy for its seasonal appearance in given localities and subsequent disappearance. In Eastern Atlantic it occurs from Iceland and Norway to North Africa and Mediterranean (Compagno, 1984).

Basking shark feeds exclusively on small planktonic organisms trapped on its gillrakers (Compagno, 1984). Several studies showed that calanoid copepods are predominant in all zooplankton samples taken in the presence of surface feeding basking sharks in Atlantic waters (Sims and Merrett, 1997). Moreover, annual changes in the availability of zooplankton prey species strongly influence basking shark patterns of movement and distribution (Sims and Quayle, 1998).

The Northern Adriatic is a productive and typical neritic zone, which generally has a cyclonic circulation and periodic inflow of oligotrophic water from the Southern and Central Adriatic (Fonda-Umani *et al*., 1992). Hydrographic conditions vary owing to depth, fresh water runoff (primarily from the Po River), and the region's fluctuating climate (Boicourt *et al*., 1999). Large annual fluctuations of temperature and salinity, especially on surface, are typical for this area owing to its geographical and hydrographical setting (Zore-Armanda, 1991). The area appears to be especially sensitive to seasonal and long-term variations in nutrient load, the impact of which depends significantly on changes in the oceanographic conditions (Degobbis *et al*., 2000).

Most of basking shark records from the coastal area of Galicia (north-west Iberian Peninsula) occurred from February to April (Valeiras *et al*., 2001). In coastal regions of northwest and east Atlantic, basking sharks occurs from April to October with a peak of sightings from May until August (Kenney *et al*., 1985; Berrow and Heardman, 1994). This pattern could be explained by displacement of basking shark populations during summer to northern areas richer in plankton resources (Valeiras *et al*., 2001).

In most of the world, basking sharks disappear in autumn and they are rarely seen during winter. A recently supported explanation is that basking sharks migrate to deep water on the continental slope during winter (Francis and Duffy, 2002). The prevailing hypothesis has been that, once in deep water, the sharks cease feeding and hibernate (Parker and Boeseman, 1954; Mathews, 1962). More recent evidence (Sims, 1999; Sims *et al*., 2003b), however, suggests that sharks do not hibernate but continue feeding at lower zooplankton densities than previously believed possible and exploit zooplankton communities in mesopelagic habitats at continental shelf and slope.

Basking sharks are a rather rare but constantly present species in the eastern Adriatic Sea (Jardas, 1996). Since the

(1) Centre of Marine Studies, University of Split, Livanjska 5/III, 21000 Split, CROATIA. [soldo@unist.hr]
(2) Institute for Marine and Coastal Research, University of Dubrovnik, PO Box 83, 20000 Dubrovnik, CROATIA.

first published record in the early nineteenth century (Naccari, 1822), their occurrence has been more frequently documented recently (Soldo and Jardas, 2002a; 2002b). In fact, contrary to the situation of other large sharks whose records were reduced, the occurrence of basking sharks in the eastern Adriatic has apparently increased. From only four records in the nineteenth century, there were 20 in the twentieth century, until year 2000 (Soldo and Jardas, 2002a; 2002b). The period January 2000 - October 2002, when research was conducted, saw a large increase in the number of basking shark sightings in the whole Adriatic. Of these, seventeen were from the eastern Adriatic.

Such a large increase of sightings could not be explained by better monitoring, as the records of these sharks, owing to their impressive size, were usually reported (mainly by fishermen). This has led Zuffa *et al*. (2001) to propose three possible explanations:

1. Climate change: certain changes in the Adriatic ichthyofauna have already been observed, linked to large-scale changes in seawater temperature and salinity (Dulčić *et al*., 1999);

2. Changes in zooplankton abundance;

3. Unknown aspects of the basking shark biology, ecology and behaviour.

As so many aspects of basking shark biology, ecology and behaviour are still not clear (Castro *et al*., 1999; Francis and Duffy, 2002), the aim of this paper is to investigate the relationship between zooplankton abundance and basking shark occurrence in the eastern Adriatic.

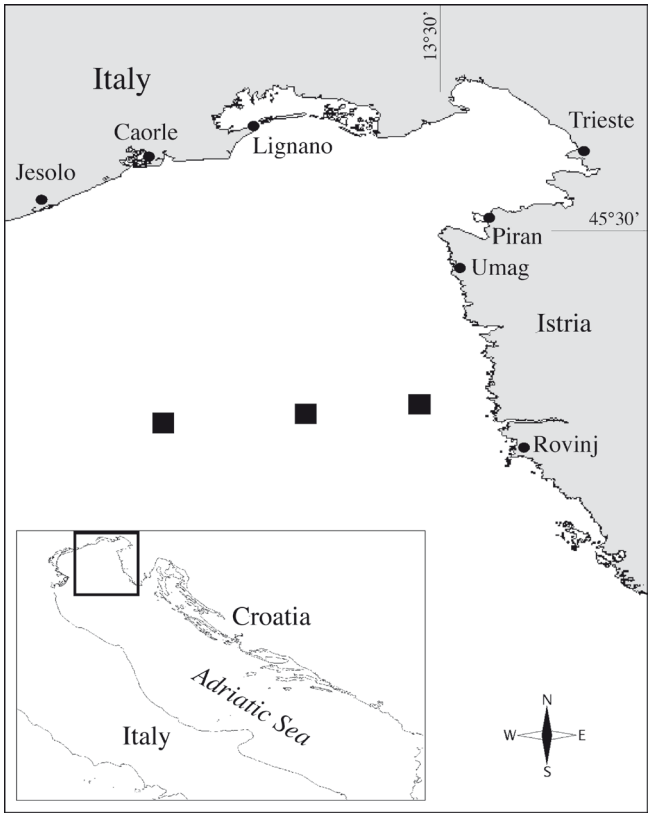

Figure 1. - Investigated area with sampling stations (■). *[Secteur étudié avec localisation des stations de prélèvements.]*

MATERIAL AND METHODS

Compilation of data was carried out from January 2000 to October 2002. Basking shark records were compiled from scientific reports (Zuffa *et al*., 2001; Soldo and Jardas, 2002a; 2002b), popular magazines and newspapers, and personal communications by other scientists, fishermen, harbor officials, etc. Only records from the northeastern Adriatic, where these sharks are usually reported, were considered (Fig. 1).

Cotton *et al*. (2005), in their research off south-west Britain, used monthly total basking sharks numbers, which were, due to the high number of records, $\log_{10}$ (x+1) transformed. However, in our research the number of basking sharks was considerably lower, so each record represents basking shark monthly occurrence in the area. When a confirmed re-sighting of a shark occurred over the two months period, those records were reported separately for each month. At the same time, sea temperature and salinity were measured monthly with Sbe 25 Sealogger CTD (Model SBE 25-03) at three fixed stations (Fig. 1), at depths of 0.3, 5, 10, 20 and 30 m (near the bottom). Furthermore, at the same stations, zooplankton samples were collected by bottom-to-surface vertical tows with a 200 μm mesh Nansen plankton net (diameter 80 cm). Samples were preserved in 2.5% formaldehyde, neutralized with a calcium carbonate buffer and then analysed with a stereomicroscope.

RESULTS AND DISCUSSION

A total of 13 basking shark records were reported (Tab. I). Most records were from March-May, similar to other Mediterranean areas (Mancusi *et al*., 2005), with one exception in July. Of these, seven records were single sightings and incidental captures of individual specimens, while others were continuous sightings of individuals or large aggregations of basking sharks over longer periods. The length of recorded sharks ranged from 249 cm to 908 cm.

Reported records were checked and confirmed (by photos, video material and personal confirmation by other scientist). However, some records have not been included in this report. Owing to deficient information, continuous sighting of one basking shark, which was eventually captured and released (records 1-2), was associated with only one single

Table I. - Records of the basking shark in the northern Eastern Adriatic from January 2000 until October 2002. Type of record: CAP - incidental capture in fishing gear; SIG - sighting at the sea. *[Signalements de requins pèlerins en Adriatique nord-orientale entre janvier 2000 et octobre 2002. Type de signalement : CAP - capture fortuite dans les engins de pêche ; SIG - aperçu en mer.]*

No.	Date	Area	Length (cm)	Sex	Remarks	Type
1-2	March-April 2000	Rovinj	700	-	Sighted several times, captured by gillnet and released.	CAP
3	22 May 2000	Piran	299	male	Captured by gillnet. Weight 120 kg.	CAP
4	19 July 2000	Piran	249	male	Captured by trammel net. Weight 70 kg.	CAP
5	22 March 2001	Umag	600	-	Sighted several times and photographed.	SIG
6	28 March 2001	Caorle	500	-	Sighted several times and photographed.	SIG
7	29 March 2001	Caorle	< 500	-	According to photo, different specimen.	SIG
8-9	March-April 2001	Piran Bay	-	-	Aggregation of 8 specimens.	SIG
10	9 May 2001	Trieste	600	-	Sighting.	SIG
11	16 March 2002	Jesolo	600	-	Sighting.	SIG
12	8 April 2002	Lignano	908	-	Caught 23 miles in front of Tagliamento estuary.	CAP
13	May 2002	Jesolo	600	-	Sighted and photographed.	SIG

Table II. - Zooplankton characteristics during period when sharks were present and absent from January 2000 until October 2002. t.z.: total zooplankton. *[Caractéristiques du zooplancton pendant les périodes où les requins étaient présents ou absents entre janvier 2000 et octobre 2002.]*

	Total zooplankton (mean no./m^3)	Copepods (mean % of t.z.)	Cladoceran (mean % of t.z.)	Thaliacean (mean % of t.z.)	Decapoda larvae (mean % of t.z.)	Other groups (mean % of t.z.)
Sharks present	6290	65.14	27.38	5.86	0.34	1.27
Sharks absent	4771	33.34	59.08	4.86	0.33	2.39

specimen, although reports show that in the same time other individuals could occur in the same area (e.g. records 6-7). Furthermore, additional records of single specimen or small basking shark aggregations were reported during March and April 2001, when large aggregation of 8 basking shark specimens (records 8-9) was reported in the same area. Before these records Zuffa *et al*. (2001) reported large aggregation of 10 basking shark specimens in the western Middle Adriatic moving toward Northern Adriatic, thus seems possible that other basking sharks may have been in the same time in that area, but again, because deficient information, all records were associated to same aggregation. Hence, several other records of unidentified species (reported by fishermen but without any photo or video evidence), with body characteristics and behaviour similar to the basking shark were also reported, but not confirmed. Nevertheless, all the additional records were reported in the same time as confirmed records. Thus, within the context of this research, which deals with monthly occurrence of the basking shark, this should not have major influence, as only the number of records may be changed.

Cushing and Dickson (1976) have distinguished four categories of biological response to climatic changes: 1. the appearance of indicator species, 2. the appearance of new populations, 3. the increase or decrease in fish stocks, based on year-class strength, 4. structural changes in the ecosystem. With reference to these categories, an increase in frequency of occurrence of some species (previously relatively, fairly or very rare) has been reported (Dulčić and Grbec, 2000). Consequently, there is a hypothetical possibility that this can be linked to the recent unusual increase of basking shark records. However, temperature fluctuations during the investigated period were typical of a neritic area, with stratification beginning as early as May and a sharp thermocline forming by early summer. During autumn, the vertical gradient weakened and a moderate temperature inversion occurred. The water column was generally isothermal in winter. Temperature ranged from 7.87 to 29.15°C (mean 16.25 ± 5.11). Salinity oscillations were more pronounced in spring and fall. Salinity ranged from 14.92 to 38.54 with a 3-year average (period January 2000 – October 2002) of 37.30 ± 1.63. Considering the high hydrographic fluctuations of the northern Adriatic, these temperatures do not differ considerably from previous investigations (Fonda-Umani, 1991). Due to intensive ingression of mid and southern Adriatic waters during 2000-2001, especially along the eastern coast (unpublished data, Rudjer Boškovic Institute - Center for Marine Research, Rovinj), salinity was higher.

Comparing occurrence of basking shark and fluctuations in temperature and salinity showed no evident pattern. Such result was predictable, as it could not be expected that temperature will have major influence on behaviour of the basking shark that migrates between boreal and warm temperate waters. The same reasoning applies to salinity, as it is known

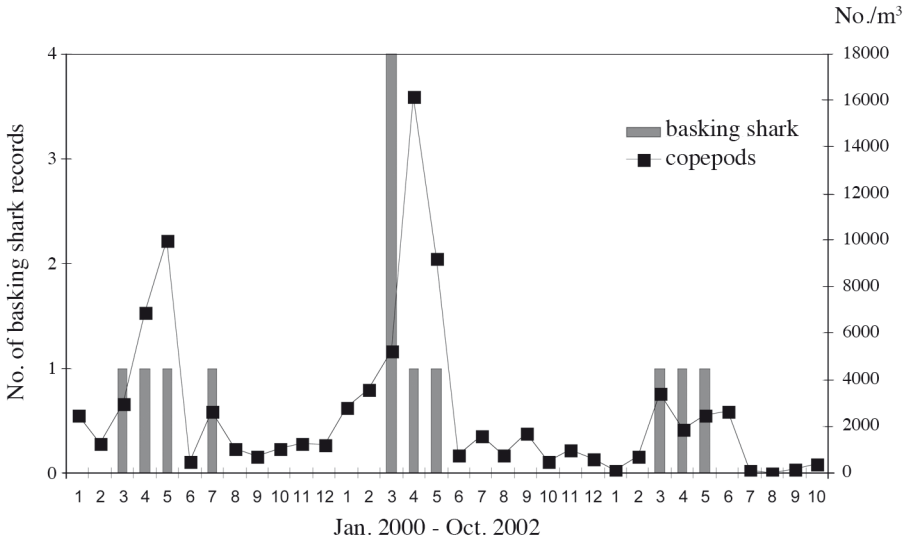

Figure 2. - Monthly occurrence of basking sharks in the northern Eastern Adriatic in relation to mean monthly values of copepods in period January 2000-October 2002. *[Occurrence mensuelle des requins pèlerins en Adriatique nord-orientale par rapport aux valeurs mensuelles moyennes des densités de copépodes durant la période janvier 2000-octobre 2002.]*

Table III. - Copepod density and species during period when sharks were present and absent from January 2000 until October 2002. *[Densités et espèces de copépodes pendant les périodes où les requins étaient présents ou absents entre janvier 2000 et octobre 2002.]*

	Copepods (no./m^3)	*Acartia clausi* (no./m^3)	*Oithona spp.* (no./m^3)	*Calanus helgolandicus* (no./m^3)	*Ctenocalanus vanus* (no./m^3)	*Temora longicornis* (no./m^3)	*Pseudocalanus elongatus* (no./m^3)
Sharks present							
Mean	3651	1330	341	196	283	145	93
SD	2438.72	998.30	166.49	170.33	79.35	98.68	66.59
Median	2817.95	766.13	101	178	148	96	68
Sharks absent							
Mean	1113	114	41	34	104	9	4
SD	680.55	178.39	39.30	61.92	127.74	14.50	9.43
Median	909	50	23	13	43	5	0

that these sharks range from brackish coastal lakes and shallow coastal waters to the open ocean (Francis and Duffy, 2002). Cotton *et al*. (2005) proposed the hypothesis, that basking sharks rely on thermal discontinuities to structure movement patterns, and hence realized distribution. Relative abundance of basking sharks was linked with climate-driven changes in sea surface temperature. However, they have restricted their hypothesis for the larger scales, as on local scale basking sharks distribution is determined largely by zooplankton abundance, particularly by the presence of adult *Calanus helgolandicus* (Sims *et al*., 2003a). Moreover, fishes for which first occurrence or increase in frequency of occurrence in the Adriatic has been reported recently are subtropical or tropical species (Dulčić and Grbec, 2000), and those changes have been observed several years before the sudden increase of basking shark records that happened over the period January 2000-October 2002. Therefore, such unusual occurrence can not be explained directly by temperature and salinity changes in the northern Adriatic.

Quantitative analyses of zooplankton showed differences between periods when basking shark were occurring and those when they were absent (Tab. II). Although density of total zooplankton during the period when sharks occurred most frequently was 1.31 times higher than in period when sharks were absent, this difference was not statistically significant ($t = 1.80$, $p > 0.08$). When sharks were most abundant, fraction of copepods in total zooplankton was 1.95 times higher than during period without shark sightings, and thaliacean was slightly higher (1.2 times), while cladoceran fraction was 2.2 times lower. There was no change in the abundance of decapod larvae. These results are similar to those obtained from previous studies of zooplankton in the presence of feeding sharks from southwest England (Sims and Merrett, 1997). This suggests the relative importance of copepods in relation to the occurrence of basking sharks.

Fishermen and scientist (Lipej, pers. comm.) observed basking sharks feeding on patches of plankton in the investigated area. Previous studies showed that basking shark is a zooplankton feeder with copepod species as the predominant prey group (Matthews and Parker, 1950; Sims and Merret,

1997; Sims *et al*., 1997). Mean monthly values of copepods from the northern eastern Adriatic, when compared with shark records (Fig. 2), suggest a relationship between copepod density and basking shark occurrence: highest values of copepods (> 1 mm in length) were reported at the same time the sharks were sighted. Copepods density during periods when sharks are reported was 3.3 times higher, which was significantly greater ($t = 4.95$, $p < 0.0001$), than when sharks were absent (Tab. III). Copepod density peaked at 9053/m^3 in April 2001, when calanoids made up 99.19% of all copepods. Such a high density of copepods could explain basking shark aggregations reported in the same period, and for the very first time, in the northern Adriatic.

Second and third peak of copepods occurred in May 2000 and 2001, but those values were considerably lower (6094 and 4516 ind./m^3, respectively). Calanoids again predominated, though at a somewhat lower fraction of the total (98 and 79%, respectively).

Especially, when the highest occurrence of basking sharks was reported, during spring in 2001, it was also the highest copepod density period of all years of our research. The mean number of copepods per m^3 in March-May 2001 was 5718, while in the same period in 2000 and 2002 it was considerably lower (4121 and 1812, respectively).

When sharks were reported, mean number per m^3 of *Calanus helgolandicus* was 5.76 times higher than when sharks were absent. This difference was statistically significant ($t = 3.60$, $p < 0.001$). Differences are even more extreme in the case of *Pseudocalanus elongatus,* as its mean number per m^3 was 23.25 times higher when sharks were present, which is significantly greater ($t = 4.54$, $p < 0.0001$). The same trend is apparent in other species: 11.66 times higher for *Acartia clausi* ($t = 4.52$, $p < 0.0001$), 8.32 times higher for *Oithona* spp. ($t = 2.34$, $p < 0.03$), 16.11 times higher for *Temora longicornis* ($t = 3.65$, $p < 0.001$), and 2.72 times higher for *Ctenocalanus vanus* ($t = 2.27$, $p < 0.03$).

Previous investigations have shown that the Adriatic has four areas with different copepod densities (Hure *et al*., 1980), the highest being in the Northern Adriatic. Highest densities, as in this work, are found in spring. Moreover, species quoted as dominant during this research, including *A. clausi, C. vanus*, *T. longicornis,* and *P. elongatus*, also were pointed out as the most dominant and common for Northern Adriatic by other authors (Hure *et al*., 1980; Fonda-Umani, 1991; Vigoni *et al*., 1998). However, *C. helgolandicus*, the third dominant species in our research, never has been identified as a dominant species in any previous study. This species has been considered as a typical winter copepod (Cateletto *et al*., 1995), while in this research, higher numbers were also recorded in spring. The fact that basking shark feeding areas are rich in *C. helgolandicus* (Sims and Merrett, 1997) supports the presumption that unusual high occurrence of basking sharks in Northern Adriatic could be due to changes in zooplankton populations. Zooplankton characteristics found during this study are similar to those from southwest England described by Sims and Merrett (1997). Further similarities with southwest England area were observed in the case of young-of-the-year sharks that appeared at the surface later in summer (male specimen of 249 cm in July 2000) (Lipej *et al*., 2000), probably due to temporal difference in arrival of newborn sharks from deep water to coastal feeding grounds (Sims *et al*., 1997). Moreover, large surface feeding basking sharks were observed mainly in March-May and never during summer. In May-June 2000 two large sharks were caught by bottom trawling offshore in deep waters (200-220 m) of Middle Adriatic (Soldo and Jardas, 2002a, 2000b). Knowing the technical characteristics of this bottom trawl (Soldo and Cetinić, 2000) it can be presumed that sharks were caught on the bottom, which leads to suggest that large basking sharks migrate from coastal to deep waters in May-June, probably due to declining of copepods density.

The reasons for the changes in zooplankton structure, and for the probable consequent increase in occurrence of basking sharks, yet cannot be explained with any certainty. However, on the basis of the results reported herein, we suggest that the increased occurrence of basking sharks in the Northern Adriatic results from a combination of high densities of large copepod species, especially *C. helgolandicus*, and lower relative densities of smaller zooplankton species.

In this regard, it is very important to underline that long-term variations in copepod biomass, particularly of *C. helgolandicus*, have already been observed in the Middle Adriatic (Vučetić, 1977). Moreover, during winter and early spring, the most abundant open sea surface copepods migrate toward the coast, especially in the shallower northern Adriatic (Hure, 1980). Periodical ingressions, observed in 2000-2001, of Levantine and Ionian water masses in the Northern Adriatic, along with their characteristic zooplankton species, are well-known (Shmeleva, 1964; Hure and Scotto di Carlo, 1969; Kršinić and Precali, 1997). Zuffa *et al*. (2001) observed a relative absence of basking sharks along Tuscany, while at the same time they observed an increased occurrence in Middle and Northern Adriatic. Distributional shift of sharks to more productive areas, caused by changes in availability of zooplankton prey species, has been already observed in the northeast Atlantic (Sims and Reid, 2002). Thus, it can be presumed that basking sharks migrate from Mediterranean toward the Northern Adriatic, following water masses carrying specific copepod species that are sufficiently abundant for their feeding, but such presumption needs to be investigated more comprehensively.

Acknowledgements. - We thank the members of the Rudjer Boškovic Institute-Center of Marine Research, Rovinj, Croatia for their information.

REFERENCES

BERROW S.D. & C. HEARDMAN, 1994. - The basking shark *Cetorhinus maximus* (Gunnerus) in Irish waters- patterns of distribution and abundance. *Proc. R. Irish Acad.*, 94B: 101-107.

BOICOURT W.C, KUZMIĆ M. & T.S. HOPKINS, 1999. - The inland sea: Circulation of Chesapeake Bay and the Northern Adriatic. *In*: Ecosystem at the Land-Sea Margin: Drainage Basin to Coastal Sea. (Malone T.C., Malej A., Harding L.W., Smodlaka N. & R.E. Turner, eds). *Coast. Estuar. Stud.*, 55: 81-129.

CASTRO J.I., WOODLEY C.M. & R.L. BRUDEK, 1999. - A preliminary evaluation of the status of shark species. *FAO Fish. Techn. Paper*, 380: 1-72.

CATELETTO B., FEOLI E., FONDA UMANI S. & S. CHENG-YONG, 1995. - Eleven years of time-series analysis on the net-zooplankton community in the Gulf of Trieste. *ICES J. Mar. Sci.*, 52: 669-678.

COMPAGNO L.J.V., 1984. - FAO Species Catalogue. Vol. 4. Sharks of the World. Part 1. Hexanchiformes to Lamniformes. *FAO Fish. Syn.*, 249 p.

COTTON P.A., SIMS D.W., FANSHAWE S. & M. CHADWICK, 2005. - The effects of climate variability on zooplankton and basking shark (*Cetorhinus maximus*) relative abundance off southwest Britain. *Fish. Oceanogr.*, 14(2): 151-155.

CUSHING D.H. & R.R. DICKSON, 1976. - The biological response in the sea to climatic changes. *Adv. Mar. Biol.,* 14: 1-122.

DEGOBBIS D., PRECALI R., IVANČIĆ I., SMODLAKA N., FUKS D. & S. KVEDER, 2000. - Long-term changes in the northern Adriatic ecosystem related to anthoprogenic eutrophication. *Int. J. Environ. Pollut.*, 13: 495-533.

DULČIĆ J. & B. GRBEC, 2000. - Climate changes and Adriatic ichthyofauna. *Fish. Oceanogr.*, 9(2): 187-191.

DULČIĆ J., GRBEC B. & L. LIPEJ, 1999. - Information on the Adriatic icthyofauna – effect of water warming? *Acta Adriat.*, 40(2): 33-43.

FONDA-UMANI S., 1991. - General features of the planktonic system in the Gulf of Trieste and their variations in the last decade. *MAP Tech. Rep.*, 47: 82-101.

FONDA-UMANI S., FRANCO P., GHIRARDELLI E. & A. MALEJ, 1992. - Outline of oceanography and the plankton of the Adriatic Sea. *In*: Marine eutrophication and population dynamics. Proceedings of the 25th EMBS (Colombo G., Ferrari I. & V. Ceccherelli, eds), pp. 347-365. Fredensborg, Denmark: Olsen & Olsen.

FRANCIS M.P. & C. DUFFY, 2002. - Distribution, seasonal abundance and bycatch of basking shark (*Cetorhinus maximus*) in New Zealand, with observations on their winter habitat. *Mar. Biol.,* 140: 831-842.

HURE J., 1980. - Vertical and horizontal distribution of oceanic copepods in the Adriatic Sea. *Acta Adriat.*, 21(2): 387-400.

HURE J. & B. SCOTTO DI CARLO, 1969. - Copepodi pelagici dell'Adriatico settentrionale nel periodo gennaio-dicembre 1965. *Pubbl. Stn. Zool. Napoli*, 37(2): 173-195.

HURE J., IANORA A. & B. SCOTTO DI CARLO, 1980. - Spatial and temporal distribution of copepod communities in the Adriatic Sea. *J. Plankton Res.,* 2(4): 295-316.

JARDAS I., 1996. - Adriatic Ichthyofauna. 533 p. Zagreb: Školska knjiga. (In Croatian)

KENNEY R.D., OWEN R.E. & H.E. WINN, 1985. - Shark distributions off the northwest United States from marine mammal surveys. *Copeia,* 1985(1): 220-223.

KRŠINIĆ F. & R. PRECALI, 1997. - On the occurrence of the oceanic tintinnines with particular consideration of the species *Amphorides laackmanni* (Jörgensen, 1924), (Ciliophora, Oligotrichida, Tintinnina) in the Northern Adriatic Sea. P.S.Z.N.: *Mar. Ecol.*, 18(1): 67-81.

LIPEJ L., MAKOVEC T., ORLANDO M. & V. ŽIŽA, 2000. - Occurrence of the Basking shark, *Cetorhinus maximus* (Günnerus, 1765), in the waters off Piran (Gulf of Trieste, Northern Adriatic). *Annales, Ser. Hist. Nat.,* 10(2): 211-216.

MANCUSI C., CLÒ S., AFFRONTE M., BRADAÏ M. N., HEMIDA F., SERENA F., SOLDO A., M. VACCHI, 2005. - On the presence of basking shark (*Cetorhinus maximus*) in the Mediterranean Sea. *Cybium*, 29(4): 399-405.

MATHEWS L.H., 1962. - The shark that hibernates. *New Sci.*, 280: 756-759.

MATTHEWS L.H. & H.W. PARKER, 1950. - Notes on the anatomy and biology of the basking shark. *Proc. Zool. Soc. Lond.*, 120(3): 356-357.

NACCARI F.L., 1822. - Ittiologia Adriatica, ossia Catalogo de' Pesci del Golfo e Lagune di Venezia. *Giorn.Fisica Nat.Pavia*, Decade II, 5: 327-340.

PARKER H.W. & M. BOESMAN, 1954. - The basking shark, *Cetorhinus maximus*, in winter. *Proc. Zool. Soc. Lond.*, 124: 185-194.

SHMELEVA A.A., 1964. - New copepod species in the Adriatic Sea and features of their distributions in connection with hydrological conditions. *Okeanologiya,* 4(6): 1066-1072.

SIMS D.W., 1999. - Treshold foraging behaviour of basking sharks on zooplankton: life on an energetic knife-edge? *Proc. R. Soc. Lond., Ser. B: Biol. Sci.*, 266: 1437-1443.

SIMS D.W. & D.A. MERRETT, 1997. - Determination of zooplankton characteristics in the presence of surface feeding basking sharks *Cetorhinus maximus*. *Mar. Ecol. Prog. Ser.*, 158: 297-302.

SIMS D.W. & V.A. QUAYLE, 1998. - Selective foraging behaviour of basking sharks on zooplankton in a small-scale front. *Nature,* 393: 460-464.

SIMS D.W & P.C. REID, 2002. - Congruent trends in long-term zooplankton decline in the north-east Atlantic and basking shark (*Cetorhinus maximus*) fishery catches off west Ireland. *Fish. Oceanogr.*, 11(1): 59-63.

SIMS D.W., FOX A.M. & D.A. MERRETT, 1997. - Basking shark occurrence off south-west England in relation to zooplankton abundance. *J. Fish Biol.*, 51: 436-440.

SIMS D.W., SOUTHALL E.J., MERRETT D.A. & J. SANDERS, 2003a. - Effects of zooplankton density and diel period on the surface-swimming duration of basking sharks. *J. Mar. Biol. Ass. U.K.*, 83: 643-646.

SIMS D.W., SOUTHALL E.J., RICHARDSON A.J., REID P.C. & J.D. METCALFE, 2003b. - Seasonal movements and behaviour of basking sharks from archival tagging: no evidence of winter hibernation. *Mar. Ecol. Prog. Ser.* 248: 187-196.

SOLDO A. & P. CETINIČ, 2000. - Determination of the most suitable construction of the bottom otter trawl in the Adriatic Sea. *In:* Contributions on the Theory of Fishing Gears and Related Marine Systems (Paschen M., Kopnick W., Niedzwiedz G., Richter U. & H.-J. Winkel, eds), pp. 65-76. Rostock.

SOLDO A. & I. JARDAS, 2002a. - Large sharks in the Eastern Adriatic. *In:* Proc. 4th Elasmbranch Ass. Meet., Livorno (Italy) 2000 (Vacchi M., La Mesa G., Serena F. & B. Séret, eds), pp. 141-155. ICRAM, ARPAT & SFI.

SOLDO A. & I. JARDAS, 2002b. - Occurrence of great white shark, *Carcharodon carcharias* (Linnaeus, 1758) and basking shark, *Cetorhinus maximus* (Gunnerus, 1765) in the Eastern Adriatic and their protection. *Period. Biol*., 104(2): 195-201.

VALEIRAS J., LOPEZ A. & M. GARCIA, 2001. - Geographical, seasonal occurrence and incidental fishing captures of basking shark *Cetorhinus maximus* (Chondrichthyes: Cetorhinidae). *J. Mar. Biol. Ass. UK*, 81: 183-184.

VIGONI V., MONTANARI G. & M.G. CORNI, 1998. - Seasonal trends of copepod dominant populations studied at two offshore sites of the Cesenatico coastline (Northern Adriatic Sea). *Oebalia*, 24: 55-75.

VUČETIĆ T., 1977. - Les investigations écologiques à long terme du zooplancton et leur application aux problèmes de la pollution. *Rapp. Comm. Int. Mer Medit*., 24(10): 109-111.

ZORE-ARMANDA M., 1991. - Natural characteristics and climatic changes of the Adriatic Sea. *Acta Adriat*., 32(2): 567-586.

ZUFFA M., SOLDO A. & T. STORAI, 2001. - Preliminary observations on abnormal abundance of *Cetorhinus maximus* (Gunnerus, 1765) in the Central and Northern Adriatic Sea. *Ann., Ser. Hist. Nat*., 11(2): 185-192.

Reçu le 15 mars 2005.
Accepté pour publication le 24 septembre 2007.